Hollow Graphite Fibers

A Novel and New Ultra-Lightweight Reinforcement for Producing Low Mass Optical Systems

Phase II SBIR Contract NAS8-00199
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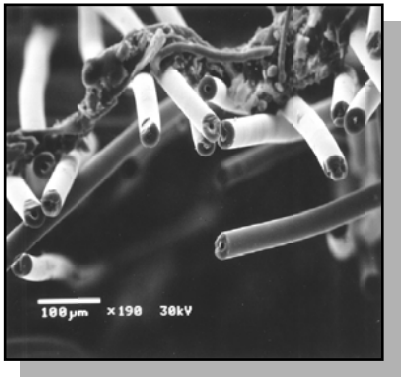
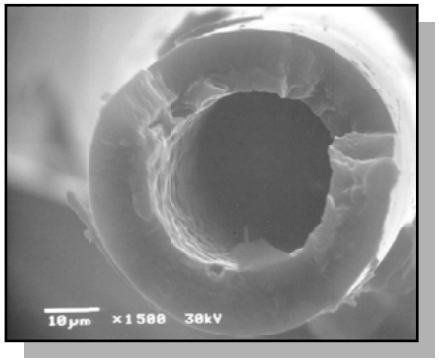
SBIR Program Objectives

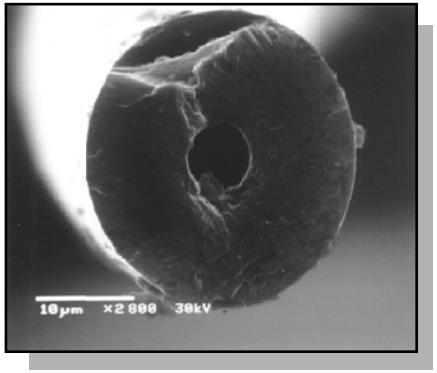
- Develop new materials to reduce optical system mass
- Develop process to produce hollow **isotropic** carbon fibers
- Use hollow fibers in composites to reduce weight by 25% – 50%
- Use hollow fibers to produce composites for optical, structural optical, and structural components
- Prepare carbon-carbon (C-C) composites with a functionally graded surface to SiC/SiC
  - 8 cm sample mirror; 0.5 m test mirror with 20 m radius
- Characterize composites (polymer and carbon matrix) using hollow isotropic carbon fiber to define structural and optical potential

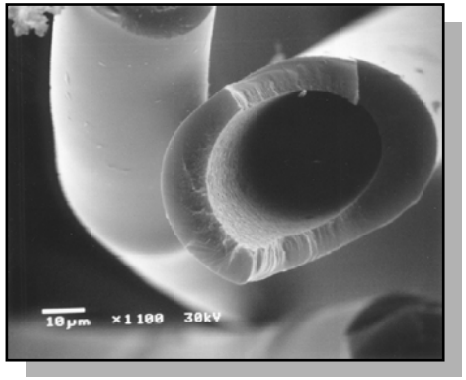
Phase I (12/99–6/00)

Phase I SBIR program demonstrated feasibility of producing hollow isotropic carbon fibers









Phase I (12/99–6/00)

- Fiber produced with strengths up to 4.2 GPa (6.1E5 psi)
- Carbon-carbon composites produced with hollow isotropic fiber compared favorably with standard commercial anisotropic carbon fiber composites as follows:

	Hollow Fiber Composite	P30X Commercial Fiber Composite
Composite Density	1.15 g/cc	1.68 g/cc
Composite Strength	149 MPa	160 MPa
Strength/Wt. Ratio	130	95

Phase II (1/01–1/04)

- Different pitch precursors being investigated and evaluated to produce hollow fibers
- Quantities of isotropic and also anisotropic fibers being produced

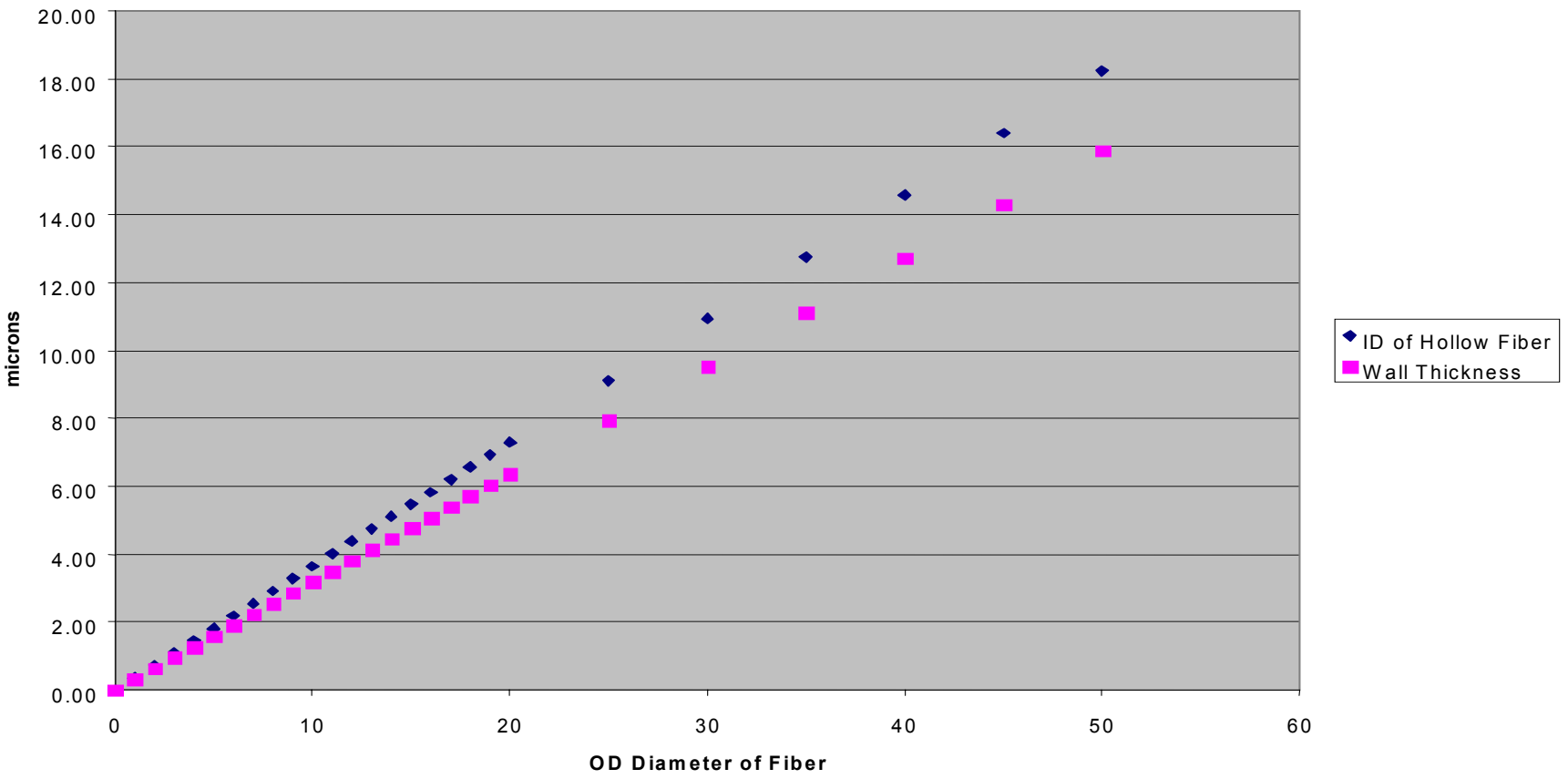
Multi-strand hollow fiber spinner development bench scale hardware

Phase II (1/01–1/04)

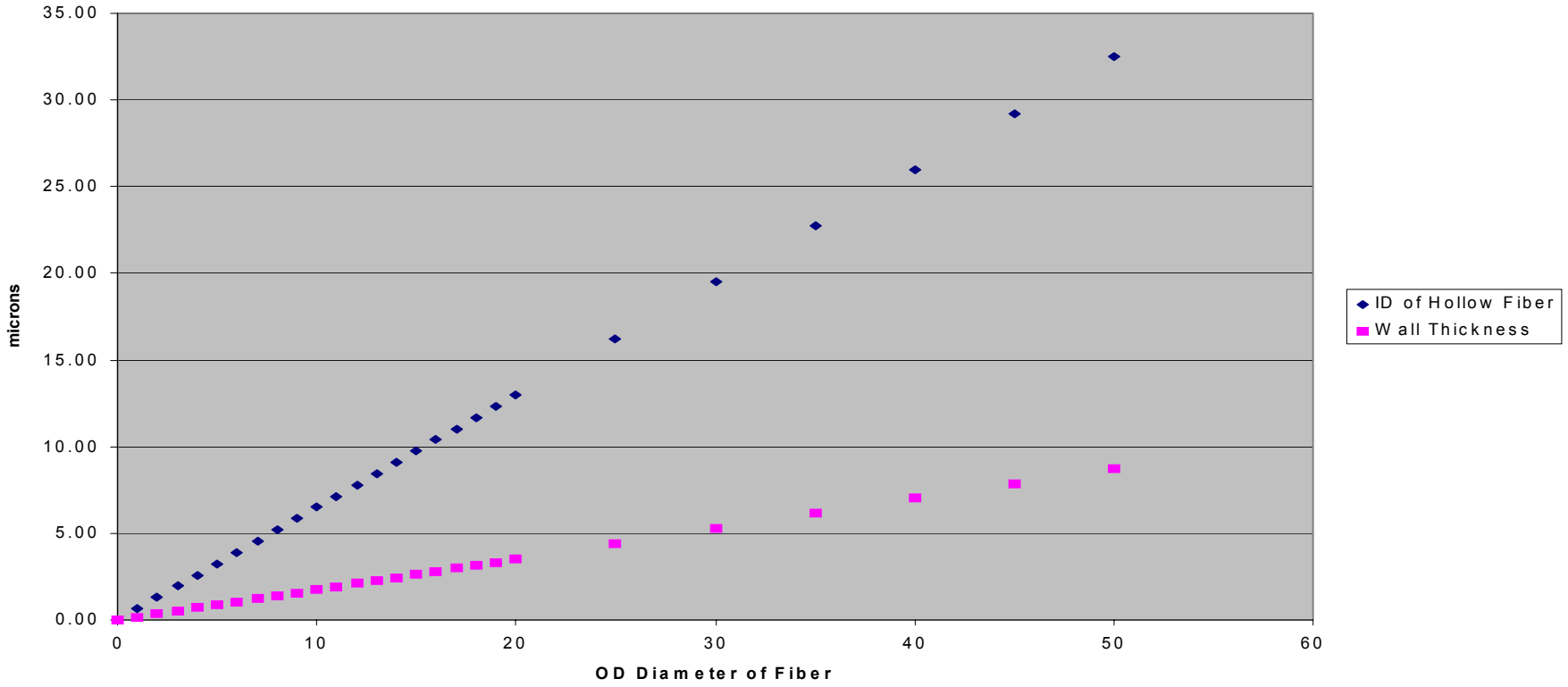
- Fiber average strengths of 1.2 GPa to 2.8 GPa being achieved
- Weight savings of 25% to 41% over solid fibers achieved
- Composite panels fabricated to verify mechanical properties – results are at least competitive with solid fiber composite panels
- Flexural strength determined by load testing
  - Hollow-fiber panels: 32% fiber by volume; 122 MPa strength
  - Solid-fiber panels: 60% fiber by volume; 100 MPa strength
- CTE testing to be conducted to compare anisotropic commercial solid-fiber vs. isotopic hollow-fiber composites
- Investigated the use of nanotubes in walls of hollow fibers
- Nanotubes doubled the strength of hollow fibers in one test

Fiber relationships to weight savings relative to commercially available 7.5μ PAN and 12 μ pitch base graphite fibers

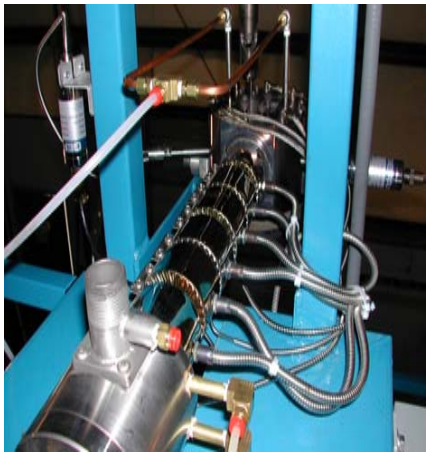
Fiber Diameter of Commercial Fiber μ	ID of Fiber to Achieve 25% Net Savings	Wall Thickness at 25% wt. Savings in μ	ID of Fiber to Achieve 50% Net Savings	Wall Thickness at 50% Wt. Savings, μ
7.5	3.14	2.18	5.03	1.24
12	4.37	3.82	7.79	2.11
OD of Hollow Fiber				
15	5.47	4.77	9.74	2.63
20	7.29	3.63	12.99	3.5



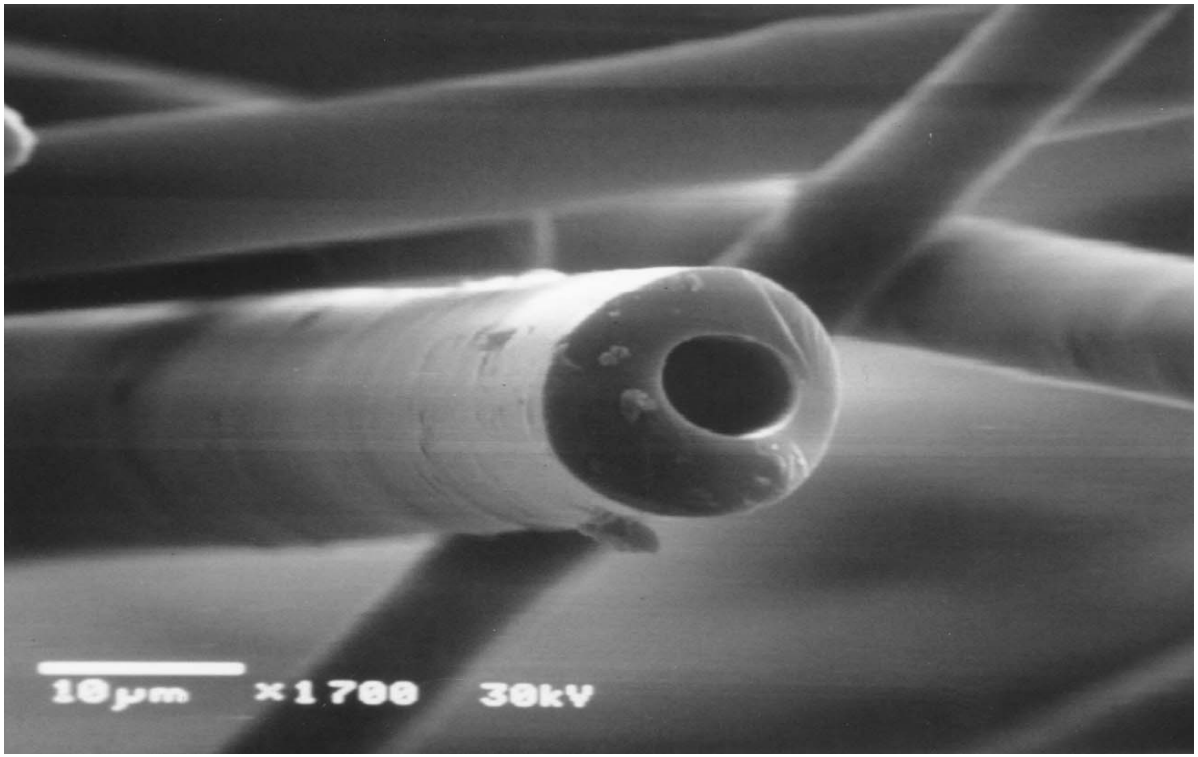
25% wt % savings over similar diameter C fiber



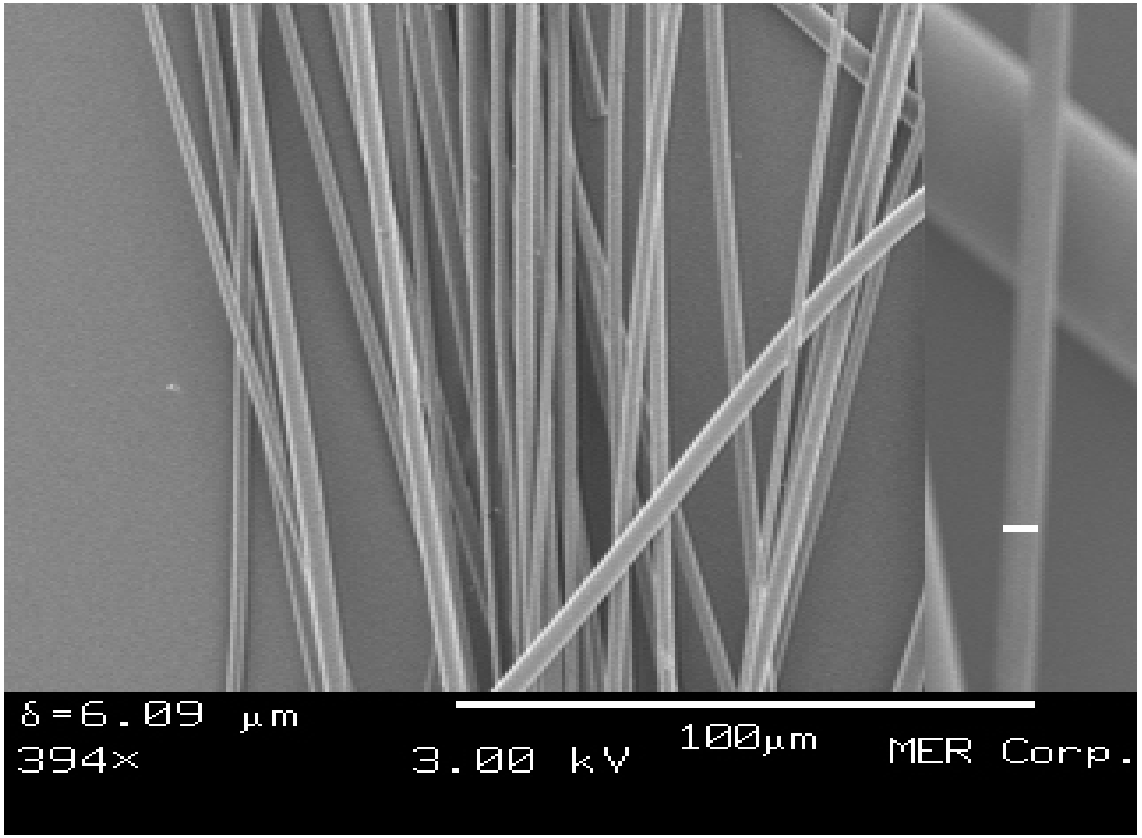
50 wt % savings diameter C fiber.



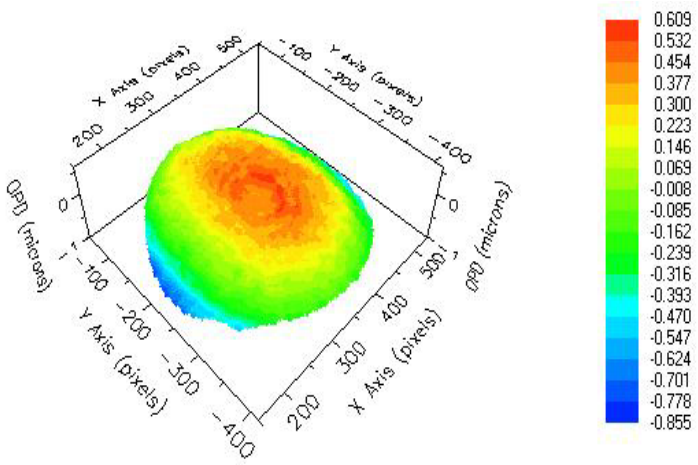
MER's Fiber Spinning Unit



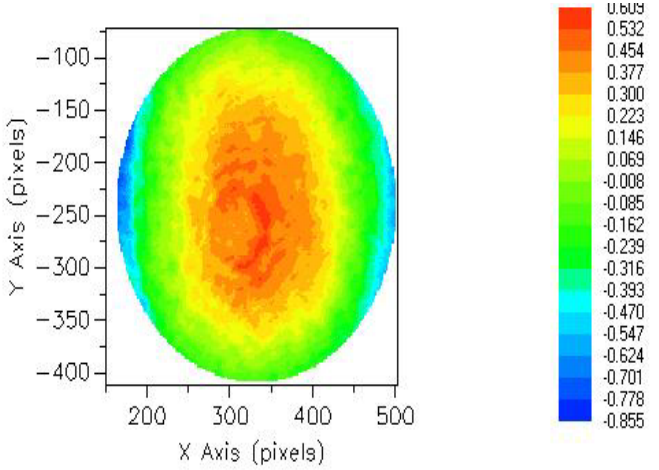
Hollow carbon fibers spun from isotropic coal-tar pitch



CTP Fibers Spun at MER



Range (PV) = 1.6575 microns, RMS = 0.2993 microns, Strehl = 0.9690
Analysis Aper: Pos[333, 241] Size[341, 341]



Range (PV) = 1.6575 microns, RMS = 0.2993 microns, Strehl = 0.9690
Analysis Aper: Pos[333, 241] Size[341, 341]

Interferogram of 4” Hollow Fiber Mirror

Mag: 50.9 X

Mode: VSI

Surface Data

Surface Statistics:

Ra: 7.53 nm

Rq: 10.64 nm

Rz: 161.92 nm

Rt: 542.08 nm

Set-up Parameters:

Size: 184 X 120

Sampling: 660.40 nm

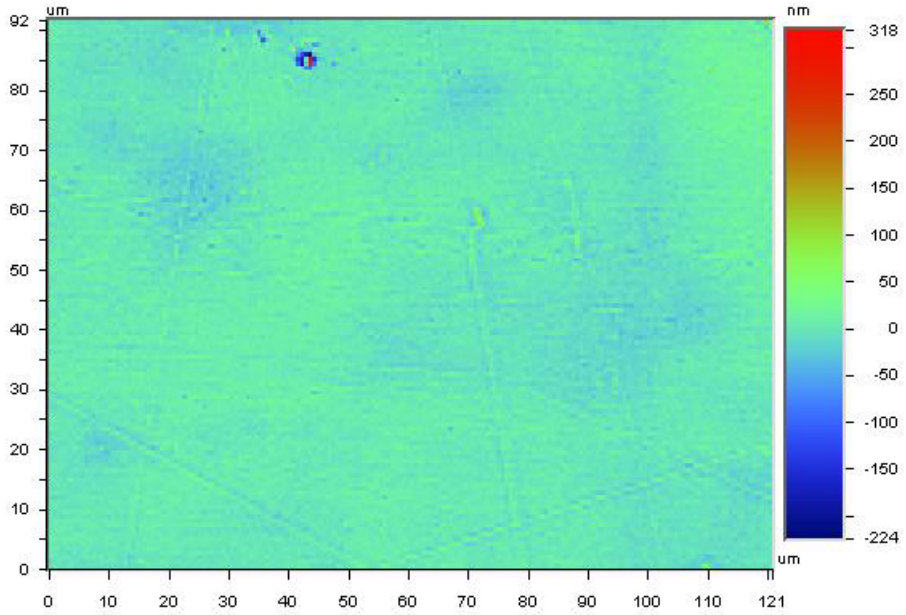
Processed Options:

Terms Removed:

Tilt

Filtering:

None

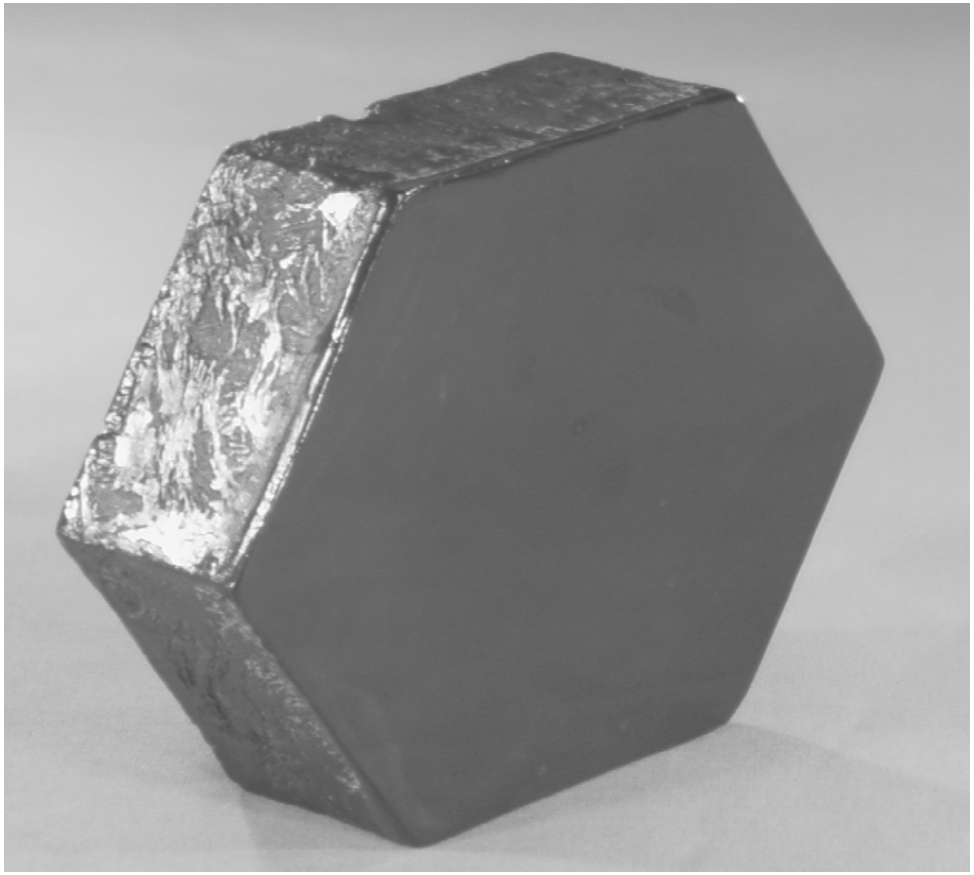


Title: Solgel on Composite

Note: Polished Surface

Fig. 2

Micro roughness of the Sol-Gel (TEOS) Coated Mirror



A Hollow Fiber Based Space Mirror

Future

- **Developing materials and techniques for making mirrors**

  - C-C structure using both isotropic solid and hollow fibers

  - Optical surface coating and polishing techniques
- **Will deliver 8 cm and 0.5 m diameter hollow-fiber mirror**
- **MSFC will run same tests on 0.5 m hollow-fiber mirror as those run on 0.5 m AMSD mirrors**